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SPECTRA AND SHAPE OF COMPLEX PULSES REFLECTED FROM A SLATTED SU--ETC(U)

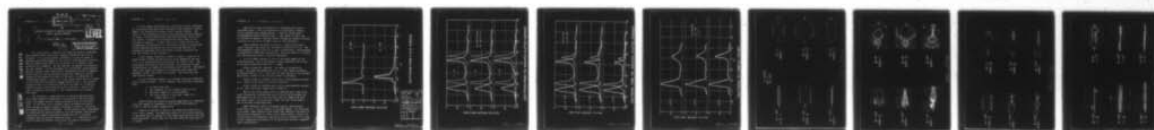
1964

M E DRUSHEL, A F WITTENBORN

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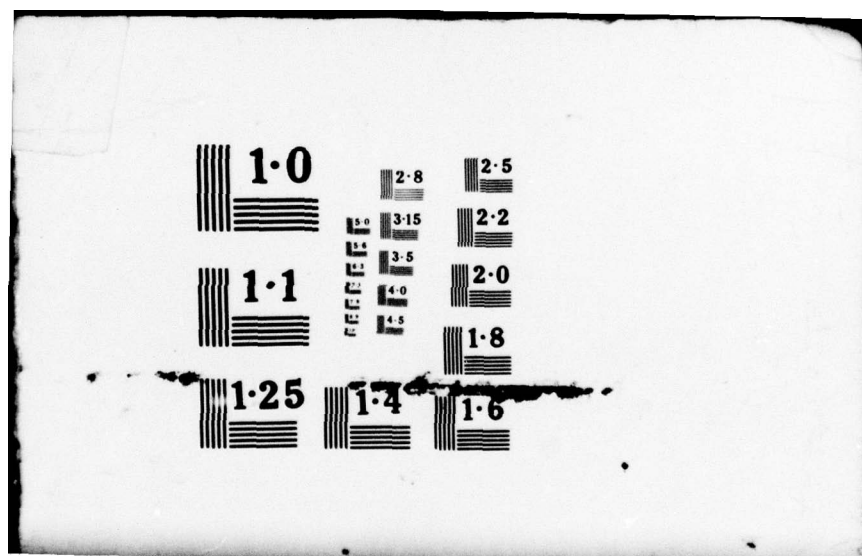
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SPECTRA AND SHAPE OF COMPLEX PULSES REFLECTED
FROM A SLATTED SURFACE,

LEVEL II

M. E. Drushel and A. F. Wittenborn

⑪ 1964

TRACOR, Inc.
Austin, Texas

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As is well known, computers and computing machine technology have enjoyed rather spectacular advances during the past ten or so years. It is quite natural, therefore, to look for means of applying these developments to the field of architectural acoustics. One such application, which is very broad, is to simulate room acoustics on a computer. We say simulate, as opposed to calculate, for two reasons: (1) The procedure for "optimizing" room acoustics has not, in most cases, been clearly delineated so that it remains an art--which is not particularly suited for computers; and (2) because of the subjective nature of the goals, a simulation is interesting because it leads to a final result which can be listened to for subjective evaluation, before modifications to the acoustic characteristics of an existing structure are made or, ultimately, before actually constructing the room in question. Work of this type is presently being done at Bell Laboratories by Schroeder and others.

Our own work is aimed primarily at devising methods which will allow simulation techniques to be applied to the relatively small, low budget acoustic design problem as well as the larger jobs. To this end, we are working toward providing the proper basic package of general computer programs to provide a practical and commercially useful technique. We are pursuing this development by minimizing the required computer size and computer time and by introducing suitable compromises between the use of recorded analogue data and computer generated data, i.e., finding the right kind of trade-off between conventional and digital procedures.

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↙ In this paper we will present some results which, although not necessarily new, have been obtained by the simulation process, namely, the reflection of pulses from a slatted surface. The result of the reflection of sound from arbitrary surfaces depends, of course, on both differential amplitude and phase shifts over the surface, in addition to differential travel times to the listener or receiver. At this point, all of these factors can be adequately accounted for in a practical fashion by introducing certain measured parameters for the scattering material for attenuation and phase shift and using a cosine scattering law over the surface of the scatterer. ↗

A very simple situation is shown in Slide 1. Here an incident pulse at 3000 cps and duration 10 ms (bandwidth 100 cps) ($B\tau = 1$) is reflected from a flat plate 4 ft wide ($\approx 12\lambda$). The slide shows the relative sound pressure, as a function of angle of reflection, for angles of incidences of 45° and 60° . The dashed line at 45° angle of incidence is a measured curve (Lane and McKinney) using a flat piece of transite. The slide does not show absolute values.

In the following examples, the incident pulse was reflected from a slatted surface. In all examples, the following conditions hold:

1. 12 slats were used
2. The frequency of the incident pulse is 3 kc.
3. The pulse length is 10 milliseconds.
4. The total width of 1 slat and 1 space is 4 inches (about a λ).

Slide 2 shows the relative pressure amplitudes as a function of θ_r for angles of incidences of 45° and 60° with widths of 1-1/2, 1, and 1/2 inches, respectively.

Slide 3 is similar to Slide 2, but shows slat widths of 2, 2-1/2, and 3 inches. The amplitude effect of the cosine scatterer is decreased near 0° because of more phase cancellation as the slat width increases. Recall that for the flat plate the peak near 0° is absent.

Thus far, we have illustrated our simulation only with a sinusoidal pulse. Once the simulation is established, however, we may consider more complex pulses -- that is, pulses with a time-bandwidth product greater than 1. Any pulse, in fact, can be recorded on magnetic tape and passed through an analog-to-digital converter for use as an incident pulse in the simulation.

Three examples are shown in Slide 4. These pulses have a center frequency near 3000 cps, and have a duration of 10 ms. The time-bandwidth products are 10, 4, and 2 respectively, corresponding to bandwidth of 1000, 400, and 200 cps. The slot width is 2 inches. Note the smoothing effect of greater bandwidth.

It is of some interest to look at the pulse shapes of the reflected pulse. Due to the volume of data concerned, only a few of the more interesting ones will be shown.

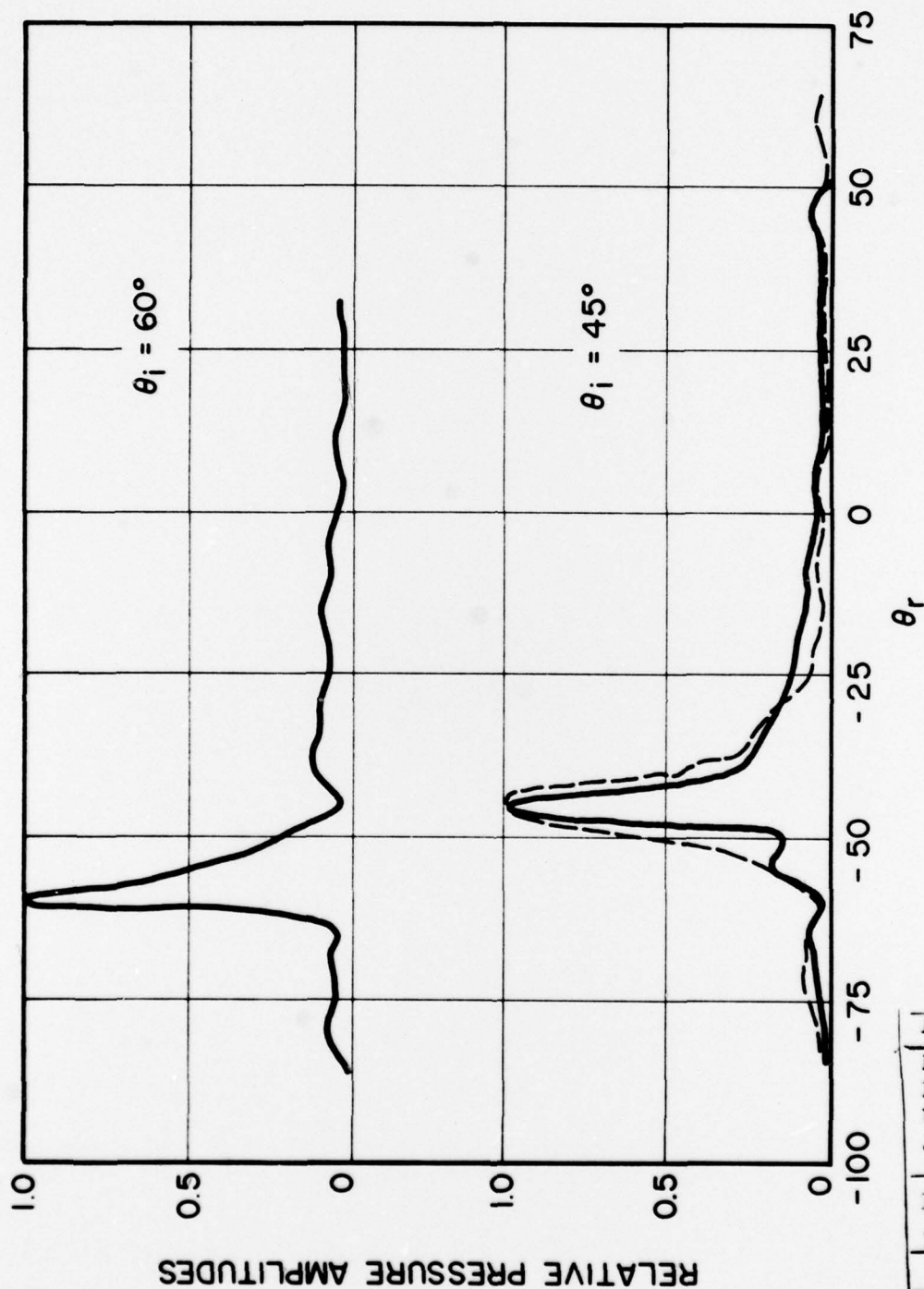
Slide 5 shows the sinusoid. The angle of incidence is at 60° . The amplitude peaks occur at $\theta_r = -60^\circ$ (where incidence = reflection) and $\theta_r = +5^\circ$. Note that the gain factor on the recorder was varied in order to show as much detail as possible.

Slide 6 shows an incident pulse with a time-bandwidth product of 4. (This is the case of a chirp or whistle.)

Slide 7 shows an incident pulse with a time-bandwidth product of 10. Note the mirror image effect around 5° .

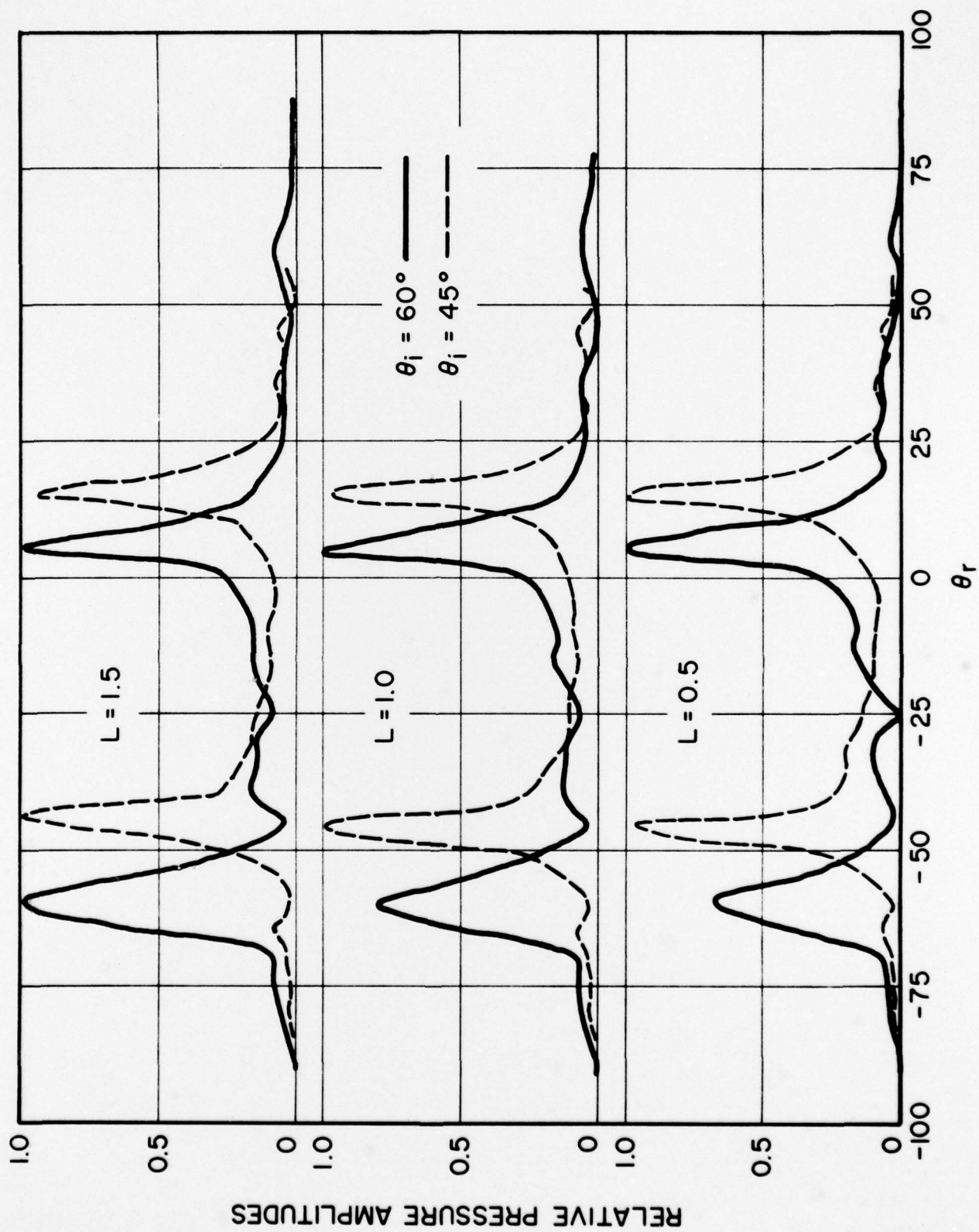
Many of the pulse shapes which we examined were found to be quite interesting, although they are of little value because the amplitudes are too low to be actually heard in competition with the direct pulse. For curiosity's sake, the last slide shows a few of the more interesting ones.

Other diffusers such as corrugated panels, semicircular structures, etc., can be treated in the same manner. At this point in our work, there remains little doubt that complete structures or rooms can be simulated in a practically useful manner, always with the end result of producing a tape which can be listened to in order to get a subjective evaluation of the particular acoustic treatment under consideration.

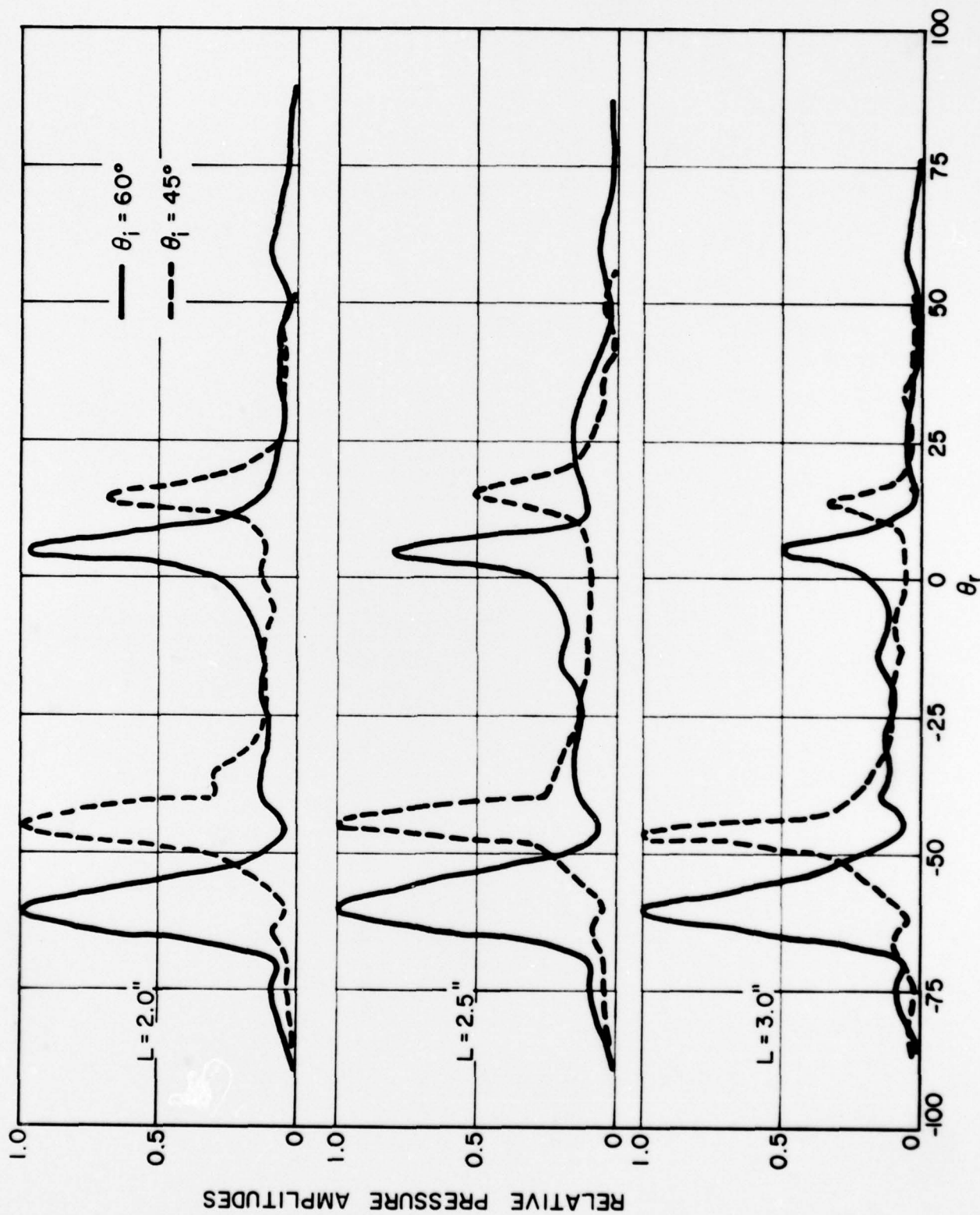


SCATTERING FROM A FLAT SURFACE

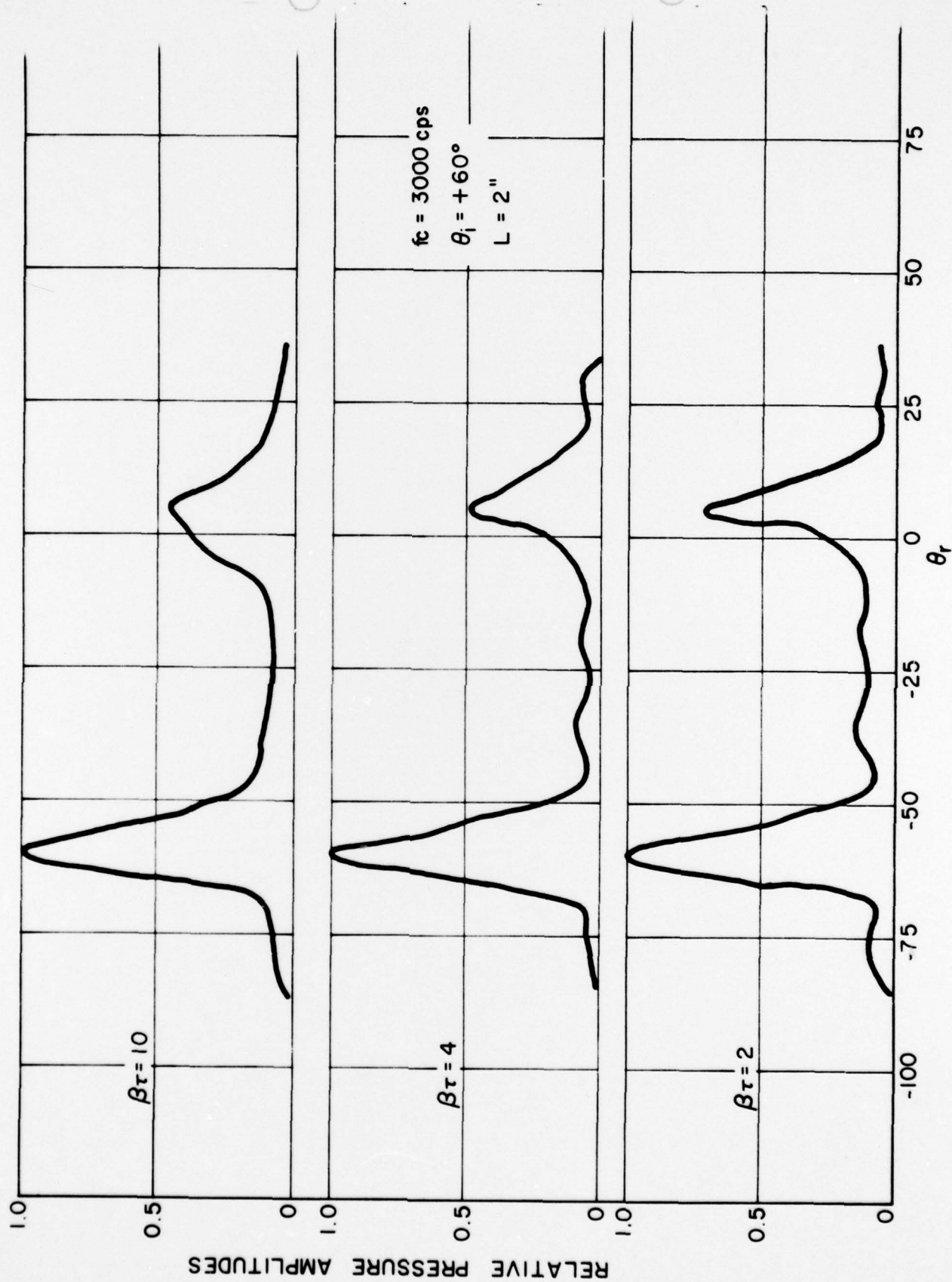
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SCATTERING FROM THE INDICATED SLATTED SURFACES

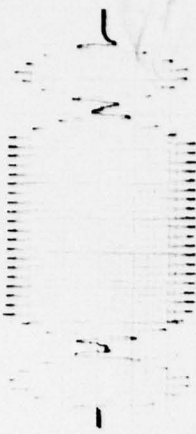


SCATTERING FROM THE INDICATED SLATTED SURFACES

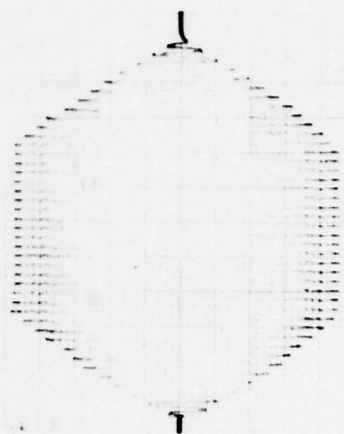


SCATTERING OF COMPLEX PULSES

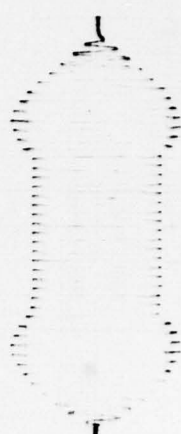
$f = 3000$
 $\beta_T = 1$
 $\theta_i = 60^\circ$



$\theta_r = 0$
 $GAIN = 1$

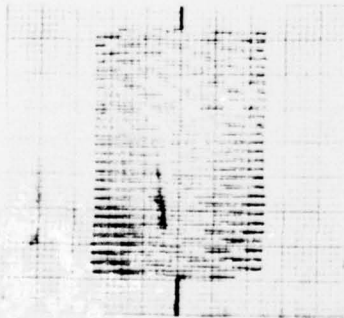


$\theta_r = 5$
 $GAIN = \frac{1}{2}$

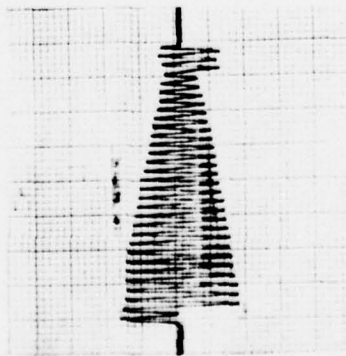


$\theta_r = 10$
 $GAIN = \frac{1}{2}$

$\theta_r = -60^\circ$
GAIN = $\frac{1}{4}$



$\theta_r = -40^\circ$
GAIN = 1



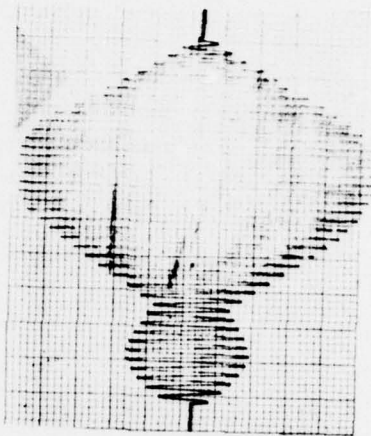
$\theta_r = -10^\circ$
GAIN = 1



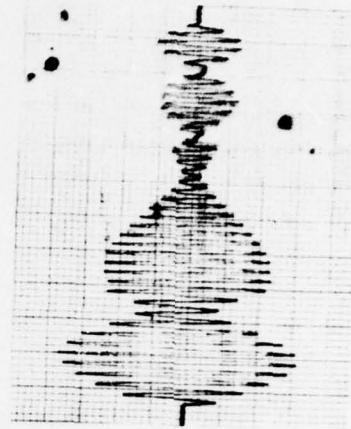
$\theta_r = 0$
GAIN = 1



$\theta_r = 5^\circ$
GAIN = $\frac{1}{2}$

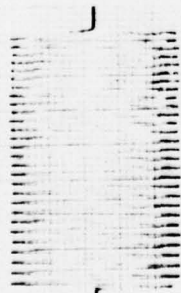


$\theta_r = 15^\circ$
GAIN = 1



$$\theta_r = -60^\circ$$

$$\text{GAIN} = \frac{1}{4}$$



$$\theta_r = -40^\circ$$

$$\text{GAIN} = 1$$



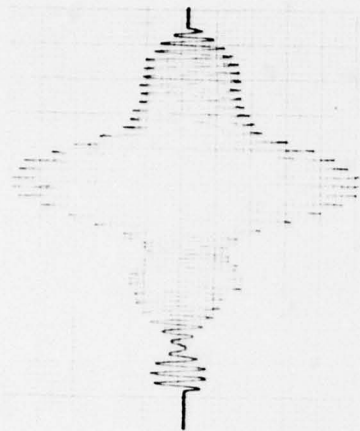
$$\theta_r = -20^\circ$$

$$\text{GAIN} = 1$$



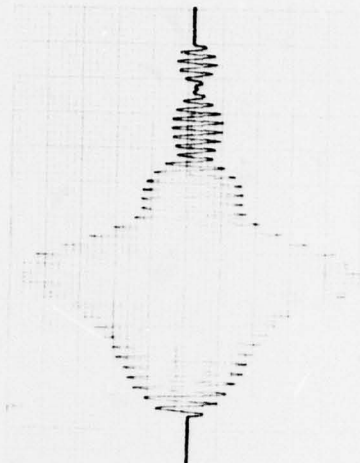
$$\theta_r = 0$$

$$\text{GAIN} = \frac{1}{2}$$



$$\theta_r = 5^\circ$$

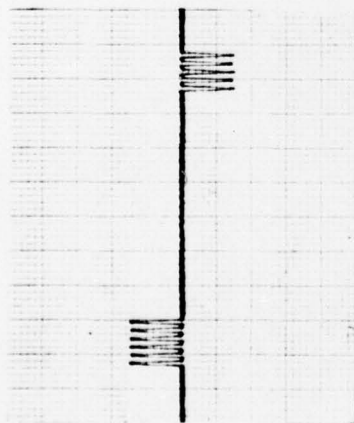
$$\text{GAIN} = \frac{1}{2}$$



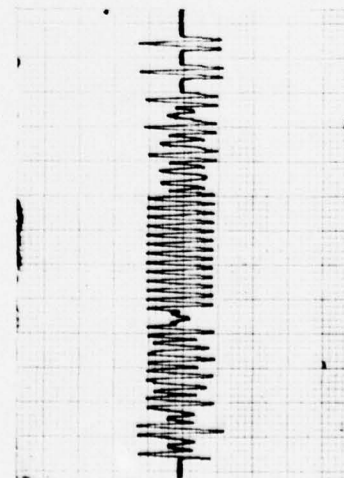
$$\theta_r = 20^\circ$$

$$\text{GAIN} = 1$$

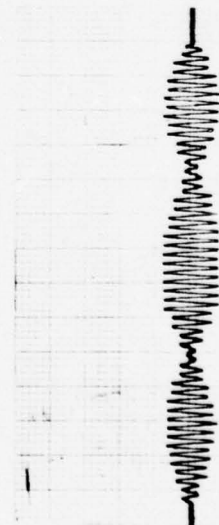




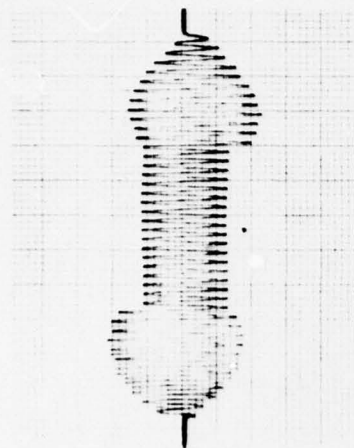
$\theta_i = -25^\circ$
 $L = \frac{1}{2}$ "



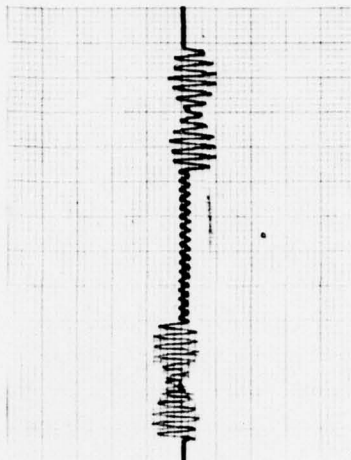
$\theta_i = 40^\circ$
 $L = \frac{1}{2}$ "



$\theta_i = 80^\circ$
 $L = \frac{1}{2}$ "



$\theta_r = 0$
 $L = 3$ "



$\theta_r = 25^\circ$
 $L = 3$ "



$\theta_r = 35^\circ$
 $L = 3$ "

